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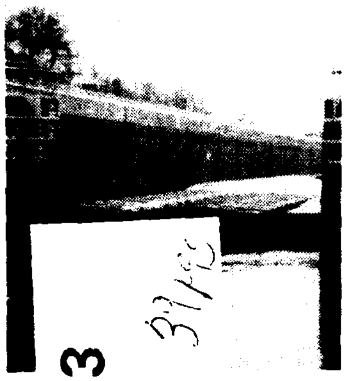
REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

US Army Corps of Engineers

SUPPLEMENT TO TECHNICAL REPORT REMR-OM-08

REMR MANAGEMENT SYSTEMS—NAVIGATION STRUCTURES

MANAGEMENT SYSTEM FOR MITER LOCK GATES



by

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Final Report

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GT	Geotechnical	EI	Environmental Impacts
HY	Hydraulics	OM	Operations Management
CO	Coastal		

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BOTTOM - Lock No. 19, Keokuk, Iowa.

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13. ABSTRACT (Maximum 200 words)

The U.S. Army Corps of Engineers established a Repair, Evaluation, Maintenance, and Rehabilitation (REMR) program to focus more attention on deterioration and maintenance rates of civil works structures. An Iowa State University (ISU) research team has implemented this program and developed rating and maintenance procedures for miter lock structures as well as other structural components. This supplement describes and documents updates to the original inspection procedure and rating rules for miter lock gate structures. The changes have been recommended by Corps personnel as a consequence of the application of the initial procedure.

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PREFACE

This study was authorized by Headquarters, US Army Corps of Engineers (HQUSACE) under Civil Works Research Unit 32280, "Development of Uniform Evaluation for Procedures/Condition Index for Deteriorated Structures and Equipment," for which Dr. Anthony M. Kao is Principal Investigator. This work unit is part of the Operations Management problem area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program sponsored by HQUSACE. Mr. James E. Crews (CECW-O) is the REMR Technical Monitor for this work.

Mr. Jesse A. Pfeiffer, Jr. (CERD-C) is the REMR Coordinator at the Directorate of Research and Development, HQUSACE; Mr. Crews and Dr. Tony C. Liu (CECW-ED) serve as the REMR Overview Committee; Mr. William F. McCleese (CEWES-SC-A), US Army Engineer Waterways Experiment Station, is the REMR Program Manager. Dr. Kao is also the Problem Area Leader for the Operations Management problem area.

The study was performed by the College of Engineering, Iowa State University, under contract to the US Army Construction Engineering Research Laboratories (USACERL). Principal Investigators for Iowa State University were Professors Lowell Greimann and James Stecker. Kevin Rens was the research assistant.

In 1990, inspection procedures and condition index rating rules for miter gates were published in REMR Management Systems-Navigation Structures, Management System for Miter Lock Gates, Technical Report REMR-OM-08. Since that document was published, updates to the rules and procedures have been made to reflect input by several Corps of Engineers personnel. The updated rules are described in this supplement.

The study was conducted under the general supervision of Dr. Paul A. Howdyshell, Chief of Engineering and Materials Division (EM) of USACERL, and under the direct supervision of Dr. Kao, CECER-EM, who was the Contracting Officer's Representative. The USACERL technical editor was Gloria Wienke, Information Management Office.

COL Daniel Waldo, Jr., is Commander and Director of USACERL and Dr. L.R. Shaffer is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	0.0254	metres

REMR MANAGEMENT SYSTEMS NAVIGATION STRUCTURES MANAGEMENT SYSTEM FOR MITER LOCK GATES

PART I: INTRODUCTION

Background

The US Army Corps of Engineers established a Repair, Evaluation, Maintenance, and Rehabilitation (REMR) program to focus more attention on deterioration and maintenance rates of civil works structures. An Iowa State University (ISU) research team has implemented this program and developed rating and maintenance procedures for miter lock gate structures (Greimann, Stecker, and Rens 1990) as well as other structural components. The purpose of this supplement is to describe and document updates to the original inspection procedure and rating rules for miter lock gate structures. The changes have been recommended by Corps personnel as a consequence of the application of the initial procedure.

The concepts and ideas for the inspection and rating of miter lock gates is based on previous work for steel sheet pile structures (Greimann and Stecker, 1990). Structural adequacy was measured by a factor of safety that formed the basis for the structural condition index. The factor of safety for miter gates was calculated by structural analysis software (US Army Corps of Engineers, 1987). Serviceability considerations and subjective judgments about safety were combined into a functional condition index, which was based on field measurements of distresses and opinions of experts. An engineer may judge that a safety problem is likely even though it is not quantifiable by measurements or simple calculations. For example, cracks or dents may be critical or noncritical, depending on the location and orientation.

Motivation for Updates

During the validation and training of the miter lock gate maintenance and repair program, it became clear that a structural analysis of horizontally framed gates could not be performed for a large number of gates. The assumptions that went into the development of the structural analysis software were valid for only a particular type of gate configuration. Additionally, the software performed a structural analysis of the as-designed structure as detailed in construction drawings and not the current in-place structure. Deterioration due to cracks, dents, corrosion, and wear were not accounted for in the software. In summary, the structural analysis did not seem to be warranted. The software does, however, evaluate the as-designed structures based on 1987 allowable stress design criteria.

Additionally, structural analysis software for vertically framed gates and many other structures in a navigation lock system is not available.

After several meetings with Corps personnel, it became clear that many structural considerations were already embedded in the functional rules in the form of subjective safety as mentioned in the previous paragraphs. The experts took many structural factors into account when setting limiting values, tolerances, and weight factors. For example, embedded anchorage movement and contact offset of the miter blocks were really indicators of structural problems. With this in mind, it was decided that, in lieu of the structural factor of safety calculation, the current structural adequacy could be better described by some of the distress measurements. All the distresses and descriptions are listed in Table 1. Table 2 lists the separate sub-distresses contained within each distress (Greimann, Stecker, and Rens 1990). A subset of distresses were selected from Table 2 that have a more significant impact on safety (Table 3). The structural condition index, as such, will be discontinued and structural problems will be indicated on the distress list if the distress measurement exceeds certain bounds. A structural note along with the corresponding measurement will be included in the summary report to flag potential structural problems. A structural analysis is left as an option to the user but is not included as a part of the condition index calculation. The functional condition index will, henceforth, be referred to as the condition index; the word functional has been dropped.

Supporting Material

For management purposes, the condition index scale (0 to 100) is calibrated to group structures into three basic categories or zones. For the lowest zone (0 to 39) a detailed evaluation is required to determine the need for repair, rehabilitation, or reconstruction. As part of this evaluation, the tactics described in Engineer Technical Letter No. 1110-2-532, Reliability Assessment of Navigation Structures, dated 1 May, 1992, should be used.

Table 1

Distresses for Miter Lock Gates

Distress	Brief Description
Anchorage movement	Motion of the upper anchorage system during gate operation
Elevation change	Vertical displacement of the gate during operation
Miter offset	Misalignment of the bearing blocks at the miter point
Bearing gaps	Gaps between the bearing blocks at the quoin and miter
Downstream movement	Downstream displacement of the miter point as the head is applied
Cracks	Breaks in the structural steel components
Leaks, boils	Water passing through or around the gate
Dents	Disfiguration of steel components
Noise, jump, vibration	Abnormal noise, vibration, or jumping during gate operation
Corrosion	Loss of steel due to interaction with the environment

Table 1

[illegible]

Distress	[illegible]
Anchorage movement	Concrete/steel interface
	[illegible]
	Gudgeon pin
Elevation change	Quoin
	Miter
Miter offset	Contact
	Angular
Bearing gaps	Quoin
	Miter
Downstream movement	
Cracks	Girders
	Intercostals
	Skin plate
Leaks and boils	Skin leaks
	Quoin and miter leaks
	Boils
Noise, jumping, vibration	Noise
	Jumping
	Vibration
Dents	Girders
	Intercostals
	Skin Plate
Corrosion	Girders
	Intercostals
	Skin Plate

[illegible]	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
Damping	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

PART II: FIELD INSPECTION

Overview of the Inspection Form

Only minor updates have been made to the inspection form. The inspection form has been designed to provide flexibility in documenting a variety of field conditions on one standard form. Though there are nine pages in the inspection form, data for the last four are optional and need be entered only if structural analysis is required. Refer to the main report for more detail on the structural analysis portions of the inspection form (sheets 1 through 9 on pages 24 through 40 of the main report). The following section illustrates the updates of the condition index portions of the inspection form. Only sections where updates have occurred are listed. A complete, updated inspection form is in the Appendix to this supplement.

Update 1, Page 3

FACING DOWNSTREAM AT [illegible] GATE, [illegible]

LEFT LEAF ______________

RIGHT LEAF ______________

Comments:

Record the orientation of the miter lock gates [illegible] and identifying the left and right leaves as L, R [illegible].

Update 2, Page 3

ELEVATIONS OF GATE LEAF

REFERENCE ELEVATION: LEFT LEAF ________ RIGHT LEAF ________

Comments:

ELEVATIONS OF GATE LEAVES: [illegible] the concrete lockwall. The [illegible] of the permanent benchmark should be identified on Page 2, OTHER COMMENTS.

Update 3, Page 3

ANCHORAGE SYSTEM MEASUREMENT [illegible] 1, 2, 3

IS THE ANCHORAGE SYSTEM RIGID OR FLEXIBLE? R F ________

IF FLEXIBLE, LENGTH OF FLEXIBLE ANCHOR BAR: in. ________

	CRACKED CONCRETE		ANCHOR CORROSION (Level 3 or greater)	
	LEFT LEAF	RIGHT LEAF	LEFT LEAF	RIGHT LEAF
PARALLEL ARM:	(Y N)	(Y N)	(Y N)	(Y N)
PERP. ARM:	(Y N)	(Y N)	(Y N)	(Y N)

Comments:

ANCHORAGE SYSTEM MEASUREMENT: The parallel and perpendicular anchorage arms are parallel and perpendicular, respectively, to the lock chamber. Refer to the structural drawings of the anchorage system to determine if the anchorage system is rigid or flexible. Flexible anchorages are intended to move during gate operation and are often long embedded bars which are coated by an asphalt impregnated cork lining. Rigid anchorages are usually an embedded steel frame with little flexibility. The length of the embedded anchorage is measured from the face of the concrete to the end of the concrete embedment. Indicate the presence of excessive concrete cracking at location 1 (Figure 10, Greimann et al 1990) where the anchorage enters the concrete. Also, record the existence of Level 3 or greater corrosion on the anchorage system configuration. Excessive concrete spalling may indicate that a displacement occurred at this location at some point in time and may or may not show up at a current measurement. Small hairline cracks, probably caused by thermal expansion or contraction of the concrete, should be ignored in this analysis.

Update 1, Page 4

MITER AND QUOIN BEARING MEASUREMENTS

OFFSET OF MITER BLOCKS WITH GATE AT MITER (1'HEAD), (DIM. 4, 5)

LOCATION	MEASUREMENT (in.)	DISTANCE BELOW TOP GIRDER (ft)	GATE DOWNSTREAM
TOP:	______	______	(L/R/NA) ______
DSWL:	______	______	(L/R/NA) ______

(DSWL = DOWNSTREAM WATER LEVEL WITH 1' HEAD ON GATE)

Bearing block width : (in.) ______

Comments:

MITER BLOCK OFFSET: The offset of miter blocks at the top of the gate, Dimension 4, and at the downstream water level (DSWL), Dimension 5, along with the vertical distance from the walkway to each measurement can be made with a ruler and tape. Record also the width of the bearing blocks. See Figure 11 in (Greimann et al 1990) for illustration of miter offsets. The gate leaves should be in the mitered position with 1 ft of head in the chamber to stabilize the gates. In addition, record the relative position of the leaves by indicating which leaf is further downstream, left (L) or right (R), at each measurement.

<u>Sequence of Field Inspection</u>

The following is a suggested sequence of data collection for pages 3 through 5 of the inspection form for two sets of miter gate leaves. If only one set of gates is to be inspected, start at Step 1 for the upper gate or Step 9 for the lower gate.

A three-person team is required; two on top of the lockwalls and one in the boat starting above the upper gate. The two people on top should independently read and record measurements and elevation readings. Verify data before proceeding to the next step. This may eliminate serious data errors. Begin inspection of the upper gate:

1. Set up - anchor measurement devices on both gate leaves of upper gate.
   - set level and transit on land side of chamber. The transit and level should be set in a location, on either lock wall, that provides the best field view for both gate leaves.

2. With gate in closed position (no head), one person rides near gate leaf to recessed position.
   a. Take gate leaf elevations at recessed position.
   b. Record anchor measurement at recessed position.
   c. Observe and record noise, vibrations, and jumping of gate leaf as it is swung open and closed.

3. Repeat Step 2 on the other gate leaf.

4. During Steps 2 and 3, the boat person inspects upstream side of gate leaves for corrosion, dents, and cracks, and records the findings, then enters chamber when finished. The inspection personnel and lock operator should have good radio communications at all times when operating the lock.

5. Close gate leaves to near miter position (4 ft opening).
   a. Take gate leaf elevations at this position.
   b. Record anchor measurements at this position.

6. Close gate leaves to miter and drop water level in chamber 1 ft to stabilize gate and then hold level.
   a. Take gate leaf elevations at this position.
   b. Record anchor measurements at this position.
   c. Record offset of miter blocks at top and DSWL and which gate leaf is downstream.
   d. Record gaps between bearing blocks at miter and both quoins.
   e. Inspect downstream side of gate for corrosion, dents, and cracks and record findings.

7. Place rulers near miter point on near gate leaf close to walkway and at DSWL. The rulers must be placed with the <u>lowest number</u> near the gate attachment.
    a. Record longitudinal position reading of miter point from top rule and DSWL rule.

8. Lower water level in chamber so upper gate is under full head condition.
    a. During emptying of chamber,
        1) top person observe miter block and record movement.
        2) top person observe both gate leaves and record any vibrations or noise.
        3) top person and boat person observe for leaks at changing water levels during emptying.
        4) boat person inspect and record corrosion, dents, and cracks on downstream side of gate.
    b. At low water level, gate under full head pressure,
        1) top person get longitudinal position reading of miter point from top rule and DSWR rule.
        2) record anchor measurements with gate under full head pressure.

Begin inspection of the lower gate.

9. Lower water level in chamber.
    a. Boat person inspect and record corrosion, dents, and cracks on upstream side.
    b. Top people set up instruments and anchorage measurement devices.

10. With gate in closed position (no head), one person rides near gate leaf to recessed position.
    a. Take gate leaf elevations at recessed position.
    b. Record anchor measurement at recessed position.
    c. Observe and record noise, vibrations, and jumping of gate leaf as gate leaf is swung open and closed.

11. Repeat Step 10 on the other gate leaf.

12. During Steps 10 and 11, the boat person inspects both quoin areas and the downstream side of the lower gate.

13. Open gate to near miter position (4 ft opening).
    a. Take gate leaf elevations at this position.
    b. Record anchor measurements at this position.

14. Close gate leaves to miter and fill water level in chamber 1 ft to stabilize gate and then hold level.
    a. Take gate leaf elevations at this position.
    b. Record anchor measurements at this position.
    c. Record offset of miter blocks at top and DSWL and which gate leaf is downstream.
    d. Record gaps between bearing blocks at miter and both quoins.
    e. Inspect downstream side of gates for corrosion, dents and cracks and record findings.

15. Place rulers near miter point on near gate leaf close to walkway and at DSWL. The rulers must be placed with the <u>lowest number</u> near the gate attachment.
    a. Record longitudinal position reading of miter point from top rule and DSWL rule.

16. Raise water level in chamber so lower gate is under full head condition.
    a. During filling of chamber,
        1) top person observe miter block and record movement.
        2) top person observe both gate leaves and record any vibrations or noise.
        3) top person and boat person observe for leaks at changing water levels during filling.
        4) boat person inspect and record corrosion, dents, and cracks on downstream side of gate.
    b. At full water level, gate under full head pressure,
        1) top person get longitudinal position reading of miter point from top rule and DSWL rule.
        2) record anchor measurements with gate under full head pressure.

An abbreviated form of the above detailed steps is presented graphically in Figure S1.

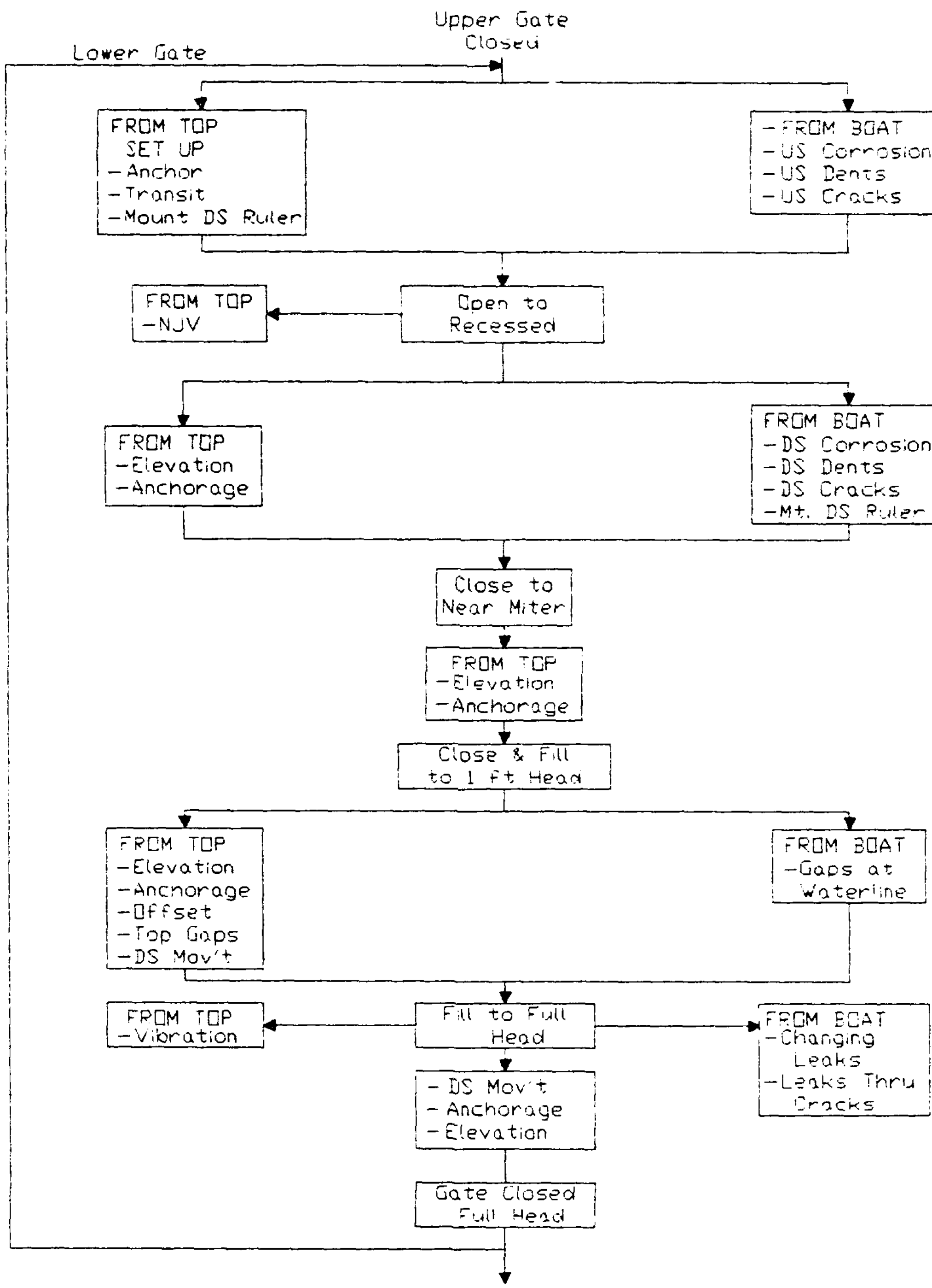

Figure S1. Graphical sequence of locking procedure.

PART III: CONDITION INDEX

The condition index involves "engineering judgment" and depends on the experience of the person making the evaluation. As such, condition index rules can be updated continually as judgements improve, more information is obtained, and more experience is gained. The experts took many factors into account as they evaluated the condition index. These factors include serviceability or performance and safety. It is the purpose of this chapter to show each of the distresses and the current updated rules and measurements. Equation numbers and section headings correspond to those in Part IV of the main report. (Note again, that the structural analysis is no longer a part of the condition index.)

A series of critical measurements, X, are made on each leaf to quantify the condition index. Experts were asked to interpret these measurements in light of the serviceability and safety of the gate and to assign limiting values, X_{max}, to the measurements. The individual distress condition index is quantified by

$$CI = 100(0.4)^{X/X_{max}} \quad [4.1]$$

Updated values of X_{max} are included below for each distress as well as any errata that may have occurred in the original report (Greimann, Stecker, and Rens 1990).

Distress Code (1): Top Anchorage Movement

Update

Some embedded anchorage systems are designed to permit movement. These types of anchorage configurations are called flexible anchorage systems. In addition, the presence of significant anchorage corrosion should be considered as an influence to gate leaf condition. These concepts have been incorporated into current rules. The following paragraph should replace paragraph 93 of the main report:

93. For rigid and frame type anchorage systems, a displacement of 0.03 in. has been selected as the limiting motion at Location 1 for all gate sizes.

$$X_{max1} = 0.03 \text{ in.} \quad [4.2a]$$

The experts judged that motion greater than this could indicate a significant structural problem. For flexible anchorage systems, a stress change of 18,000 psi was selected as a reasonable working valve. The corresponding maximum elastic motion has been selected conservatively, as

$$X_{max1} = 0.0006 \ (L) \text{ in.} \quad [4.2b]$$

where L is the length of embedded anchorage in inches. Any spalling or cracking of the concrete in this area will reduce the condition index in this area by a factor of 0.85. Additionally, a corroded anchorage configuration (level 3 or greater) will reduce the condition index by a factor of 0.85.

Errata

(none)

Distress Code (2): Elevation Change

Update

(none)

Errata

The following duplicate lines in paragraph 99 should be deleted:

The limiting X_{max} value for the change in quoin elevation has been judged to be

$$X_{max2} = 0.05 \text{ ft} \qquad [4.7]$$

Distress Code (3): Miter offset

Update

In earlier work, a maximum value of 2 in. of contact offset was permitted. Consideration was not made for the actual amount of bearing area. It was judged that 2 in. of contact offset would be excessive for a 5 or 6 in. set of bearing blocks. To account for variable width blocks, a 25 percent offset and 50 percent offset rule were incorporated as the limiting values of contact offset for horizontal and vertical gates, respectively. This gives 2 in. and 4 in. of contact offset for a 8 in. bearing block on a horizontal and vertical framed gate, respectively. The following paragraphs should replace paragraphs 105 and 108 in the main report.

105. Two types of miter offsets will be defined for horizontally framed leaves. The two types usually have different causes. The first type, contact offset, occurs when the miter bearing blocks are nominally parallel and plumb, but do not meet properly. Contact offset is measured by the maximum offset

$$X_c = \text{Maximum of absolute values } (O_1, O_5) \qquad [4.12]$$

If X_c is too large, poor bearing conditions exist and eccentricity is introduced into the leaf girders. The experts judged the limiting case to be

$$X_{maxc} = 0.25\ (BW) \qquad [4.13]$$

where BW is the bearing block width.

108. For a vertically framed gate, only the offset at the top of the miter block, O_1, is measured.

$$X = O_1 \qquad [4.17]$$

If X is too large, a poor bearing condition exists and eccentricity is introduced in the top girder as in the horizontally framed case. The limiting value for the vertically framed offset, which is not as critical as for horizontally framed, is

$$X_{max} = 0.5\ (BW) \qquad [4.18]$$

The miter offset condition index applies to both leaves.

<u>Errata</u>

Equations 4.11 and 4.14 contained typographical errors. Replace these equations with the following:

$$O = [O\,(Y - H) + O\,(H - Y)]\,/\,(Y - Y) \qquad [4.11]$$

$$X = \text{Absolute value of } (O - O) \qquad [4.14]$$

Distress Code (4): Bearing Gaps

<u>Update</u>

Several distresses in the miter lock gate inspection program involve measurements at the top of the gate and at the down stream water level (DSWL). These measurements are then extrapolated to the sill by assuming a straight line equation. In the previous work, these assumptions were applied to quoin and miter gaps. After several inspections and meetings with Corps personnel, the extrapolation assumption did not seem reasonable for quoin gaps with either floating or fixed pintles. A better assumption would be to simply take the maximum of the top and DSWL measurements. Also, it was determined that the limiting value for quoin gaps should be a function of gate height. A limiting value of 0.25 in. was chosen for low gate leaves (W/H = 2), 0.125 in for high gate leaves (W/H = 0.5), and linear between for other gate heights. Rule and limiting value updates are listed below. **Omit Equations 4.23 and 4.24 of the main report.** The following paragraph should replace paragraph 112.

112. For a horizontally framed gate, measurements of the quoin block gap will also be made at the top of the gate, QG, and at the water level, QG, under a 1-ft head situation. The X value for quoin block gaps is the maximum of the top and water level gap.

$$X = \text{Maximum } (QG, QG) \qquad [4.25]$$

A limiting value of 0.25 in. was chosen for low gate leaves (W/H = 2) and 0.125 in for high gate leaves (W/H = 0.5). For other heights, a linear equation that fits these two cases is used:

$$X_{max} = (W/H + 1)/12 \qquad [4.26]$$

Any leaks at the quoin that follow the rising (emptying) water level will reduce the condition index of the quoin by the leak factor (Equation 4.22).

Errata

(none)

Distress Code (5): Downstream Movement

(no changes)

Distress Code (6): Cracks

(no changes)

Distress Code (7): Leaks and Boils

(no changes)

Distress Code (8): Dents

(no changes)

Distress Code (9): Noise, Jump and Vibration

(no changes)

Distress Code (10): Corrosion

(no changes)

PART IV: STRUCTURAL CONSIDERATIONS

Structural safety traditionally has been measured by a factor of safety. Hence, uncertainties in material properties and loading conditions are accounted for by selecting an appropriately high factor of safety to ensure a sufficient margin between the applied loads and the structural resistance. For example, the design criteria for miter lock gates typically require a factor of safety of two.

In this project, the structural adequacy of the gate can be evaluated in two ways: 1) structural analysis with a factor of safety calculation (optional), and 2) structural notes output for the subset of structural distresses (Table 2). As discussed in Part I, the structural analysis has limitations for condition rating because it does not reflect the current condition of the structure. For information on the structural analysis theory, refer to the original project report (Greimann, Stecker, and Rens 1990).

The purpose of the structural notes is to alert the engineer that a potential structural problem may be forming. The individual distresses are flagged, based on the experts judgement, as the condition index becomes low for any of the structural distresses (Table 3). For each of the structural distresses, a note will be generated for the summary report when the structural distress condition index falls into one of three different levels:

Level 1 Note:	$55 < CI < 70$
Level 2 Note:	$40 < CI < 55$
Level 3 Note:	$0 < CI < 40$

Values of the measurement X are also included in the notes. For example, for anchorage movement Location 1, the three levels of notes are

Level 1 Note:The perpendicular anchor bar was measured to move X inches and should be monitored.

Level 2 Note:The perpendicular anchor bar was measured to move X inches and could be a problem. Further investigation may be needed.

Level 3 Note:The perpendicular anchor bar was measured to move X inches. This is potentially a structural hazard. Further investigation is needed.

The importance of the notes must be emphasized. The condition index must be a trigger mechanism for structural concerns since the structural condition index is no longer an integral part of the condition assessment.

Summary Report

Two example summary reports that detail the individual distress condition indexes and structural notes are included on the following pages. In Example 1, the optional structural analysis has been performed.

Miter Gate Structure: TEST1 - GATE1 Mon Jan 25 1993

SUMMARY REPORT

PROJECT NAME:

Test1 project

LOCATION:

gate1

Town, USA

INSPECTION DATE: 10 25 92

INSPECTED BY: G, S, R

The overall condition has been analyzed and compiled in the following indices:

CONDITION INDEX:

Right Leaf: 41

Left Leaf: 37

CONDITION INDEX

	Distress		Left Leaf	Right Leaf
**	ANCHOR SYSTEM	:	29	51
	DOWNSTREAM MOVEMENT	:	63	63
**	NOISE JUMP VIBRATION	:	70	70
**	MITER OFFSET	:	7	7
	GAP	:	93	82
**	CORROSION	:	40	29
**	DENTS	:	40	40
**	CRACKS	:	40	40
	LEAKS & BOILS	:	54	73
	ELEVATION CHANGE	:	69	83
	CI	:	37	41

Structural Notes

** ANCHOR SYSTEM
At location 1 on the left leaf, the PARALLEL anchor bar was measured to move 0.030 inches.
This is potentially a structural hazard. Further investigation is needed.

Anchor corrosion has occurred.
Cracked concrete has occurred.

** ANCHOR SYSTEM
At location 1 on the left leaf, the PERPENDICULAR anchor bar was measured to move 0.015 inches and could be a problem. Further investigation may be needed.

Cracked concrete has occurred.

** ANCHOR SYSTEM
At location 1 on the right leaf, the PARALLEL anchor bar was measured to move 0.008 inches and should be monitored.

Anchor corrosion has occurred.

** ANCHOR SYSTEM
At location 1 on the right leaf, the PERPENDICULAR anchor bar was measured to move 0.007 inches and should be monitored.

Cracked concrete has occurred.

** NOISE JUMP VIBRATION
Jumping has occurred on the right leaf. This could be a structural hazard.

** NOISE JUMP VIBRATION
Jumping has occurred on the left leaf. This could be a structural hazard.

** MITER OFFSET
The contact offset was measured to be 72 percent of the bearing block width.
This is potentially a structural hazard. Further investigation is needed.

** CORROSION
Level 3 girder corrosion was recorded on the left leaf.
Further investigation may be needed.

**CORROSION
Level 4 girder corrosion was recorded on the right leaf.
This is potentially a structural hazard. Further investigation is needed.

** DENTS
1 girder dent(s) were recorded on the left leaf. Further investigation is necessary.

** DENTS
1 girder dent(s) were recorded on the right leaf.
Further investigation may be necessary.

** CRACKS
1 girder crack(s) were recorded on left leaf.
Further investigation may be needed.

** CRACKS
1 girder crack(s) were recorded on the right leaf.
Further investigation may be needed.

STRUCTURAL FACTOR OF SAFETY

LC	INTERCOSTAL	PNL #	SKIN	PNL #	GIRDER	GRDR #
1	2.7	10	2.7	6	1.7	7
2	2.7	10	2.7	6	1.9	7
3	144.0	2	108.0	2	100.0	2
4	55.4	2	41.5	1	37.5	2
6	2.6	10	2.5	6	1.8	7

SUMMARY REPORT

PROJECT NAME:
Test2 project

LOCATION:
Gate2
Town, USA

INSPECTION DATE: 06/21/91

INSPECTED BY: Team

The overall condition has been analyzed and compiled in the following indices:

CONDITION INDEX:
Right leaf: 51
Left Gate: 55

CONDITION INDEX

	Distress		Left leaf	Right leaf
**	ANCHOR SYSTEM	:	71	32
	DOWNSTREAM MOVEMENT	:	63	63
	NOISE JUMP VIBRATION	:	100	100
	MITER OFFSET	:	85	85
	GAP	:	93	82
**	CORROSION	:	40	74
**	DENTS	:	91	40
**	CRACKS	:	40	91
	LEAKS & BOILS	:	73	87
	ELEVATION CHANGE	:	69	83
	CI	:	55	51

Structural Notes

** ANCHOR SYSTEM
At location 1 on the right leaf, the PERPENDICULAR anchor rat was measured to move 0.032 inches.
This may be a structural hazard. Further investigation is needed.
Anchor corrosion has occurred.

** CORROSION
Level 3 girder corrosion was recorded on the left leaf.
Further investigation may be needed.

** DENTS
1 girder dent(s) were recorded on the right leaf.
Further investigation may be necessary.

** CRACKS
1 girder crack(s) were recorded on the left leaf.
Further investigation may be needed.

REFERENCES

Greimann, L., and J. Stecker. 1990. Maintenance and Repair of Steel Sheet Pile Structures, Technical Report REMR-OM-9, US Army Corps of Engineers, Washington, DC.

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APPENDIX A: SAMPLE INSPECTION FORM

U.S. ARMY CORPS OF ENGINEERS
MITER LOCK GATE STRUCTURE INSPECTION

NAME OF CIVIL WORKS PROJECT:

____
____
____

LOCATION OF CIVIL WORKS PROJECT:
(1. Body of water, 2. Nearest town)
1. ______________________________
2. ______________________________

INSPECTION DATE: ____________ INSPECTED BY: ____________________

GATE IDENTIFICATION:

1. Upper gate
2. Lower gate GATE ID (no.) ____________

TYPE OF STRUCTURAL FRAMING PRESENT:

1. Horizontal
2. Vertical STRUCTURE TYPE (no.) ____________

TYPE OF PINTLE:

1. Fixed
2. Floating PINTLE SYSTEM (no.) ____________

TYPE OF SKIN PLATE:
1. Single
2. Double SKIN TYPE (no.) ____________

LENGTH OF LOCK CHAMBER: (ft) ____________________
WIDTH OF LOCK CHAMBER: (ft) ____________________
HEIGHT OF GATE LEAF: (ft) ____________________
WIDTH OF GATE LEAF: (ft) ____________________
PRESENT POOL WATER LEVELS: (ft) UPPER ____________ LOWER ____________
RECORD LOW WATER LEVEL: (ft) UPPER ____________ LOWER ____________
RECORD HIGH WATER LEVEL: (ft) UPPER ____________ LOWER ____________
DO YOU ROUTINELY DEWATER LOCK CHAMBER? (Y/N) ____________ IF YES, WHAT
YEAR WAS THE LOCK LAST DEWATERED? ____________ INTERVAL PERIOD: ____________
CONSTRUCTION DATE: ____________ OTHER COMMENTS: ____________

MITER LOCK GATE STRUCTURE INSPECTION

ARE ORIGINAL GATE LEAVES CURRENTLY IN PLACE? (Y/N) ________

IF NOT, IDENTIFY CURRENT GATE LEAF HISTORY: ________

ARE DRAWINGS AVAILABLE FOR GATE LEAVES IN PLACE? (Y/N) ________

ARE THE DRAWINGS INCLUDED WITH THIS FILE? (Y/N) ________

PAST 10 YEAR HISTORY

MAJOR MAINTENANCE, REPAIRS, OR OTHER MODIFICATIONS

	DATE	DESCRIPTION
(1):		
(2):		
(3):		
(4):		

PREVIOUS INSPECTIONS OR STRUCTURAL REVIEW (attach if available)

	DATE	DESCRIPTION
(1):		
(2):		
(3):		
(4):		

TYPE OF FENDER PROTECTION AND CONDITION OF FENDERS:

TYPE OF WALKWAY ON GATE LEAF AND CONDITION OF WALKWAY:

OTHER COMMENTS:

FACING DOWNSTREAM AT UPPER GATE, IDENTIFY GATE LEAVES AS N,S,E, or W

LEFT LEAF = ______________________

RIGHT LEAF = ______________________

OPENING AND CLOSING OF GATE LEAVES

	LEFT LEAF	% CLOSED	RIGHT LEAF	% CLOSED
DO THE DIAGONALS FLAP?	(Y/N)		(Y/N)	
DOES THE GATE JUMP?	(Y/N)		(Y/N)	
IS THERE GATE NOISE?	(Y/N)		(Y/N)	
DOES THE GATE VIBRATE?	(Y/N)		(Y/N)	

ELEVATIONS OF GATE LEAF

REFERENCE ELEVATION: LEFT LEAF____________ RIGHT LEAF________________

	RECESSED	NEAR MITER	MITER 1 ft HEAD	MITER FULL HEAD
LEFT LEAF				
QUOIN				
METER				
RIGHT LEAF				
QUOIN				
MITER				

ANCHORAGE SYTEM MEASUREMENT (Dim. 1, 2, 3)

IS THE ANCHORAGE SYSTEM RIGID OR FLEXIBLE? (R/F)____________

IF FLEXIBLE, LENGTH OF FLEXIBLE ANCHOR BAR: (in./NA)______

	CRACKED CONCRETE		ANCHOR CORROSION (Level 3 or greater)	
	LEFT LEAF	RIGHT LEAF	LEFT LEAF	RIGHT LEAF
PARALLEL ARM:	(Y/N)	(Y/N)	(Y/N)	(Y/N)
PREP. ARM:	(Y/N)	(Y/N)	(Y/N)	(Y/N)

LEFT LEAF ARM DIM. (in.)	RECESSED	NEAR MITER	MITER 1 ft HEAD	MITER FULL HEAD
PARALLEL 1:				
PARALLEL 2:				
PARALLEL 3:				
PERP. 1:				
PERP. 2.				
PERP. 3.				

RIGHT LEAF ARM DIM. (in.)	RECESSED	NEAR MITER	MITER 1 ft HEAD	MITER FULL HEAD
PARALLEL 1:				
PARALLEL 2:				
PARALLEL 3:				
PERP. 1:				
PERP. 2:				
PERP. 3:				

MITER AND QUOIN BEARING MEASUREMENTS

OFFSSET OF MITER BLOCKS WITH GATE AT MITER (1 ft HEAD), (DIM. 4, 5)

LOCATION	MEASUREMENT (in.)	DISTANCE BELOW TOP GIRDER (ft)	GATE DOWNS"REAM
TOP:			(L/R/NA)
DSWL:			(L/R/NA)

(DSWL = DOWNSTREAM WATER LEVEL WITH 1 ft HEAD ON GATES)
Bearing block width: (in.) ____________

GAP BETWEEN BEARING BLOCKS WITH GATES AT MITER (1 ft HEAD), (DIM. 6, 7)

LOCATION	MEASUREMENT (in.)	DISTANCE BELOW TOP GIRDER (ft)
LEFT QUOIN @ TOP:		
LEFT QUOIN @ DSWL:		
RIGHT QUOIN @ TOP:		
RIGHT QUOIN @ DSWL:		
MITER @ TOP:		
MITER @ DSWL:		

LONGITUDINAL POSITION OF MITER POINT (DIM. 8)

LOCATION	MEASUREMENT (in.) 1 ft HEAD	MEASUREMENT (in.) FULL HEAD	DISTANCE BELOW TOP GIRDER (ft)
TOP:			
DSWL:			

LOCK CHAMBER FILLING (OR EMPTYING)

DOES THE GATE VIBRATE? LEFT LEAF: (Y/N)
RIGHT LEAF: (Y/N)

DOES A LEAK FOLLOW THE RISING (OR EMPTYING) WATER LEVEL AND THEN CLOSE AGAIN AS THE WATER CONTINUES TO RISE (EMPTY)?
LEFT QUOIN: (Y/N)
MITER: (Y/N)
RIGHT QUOIN: (Y/N)

DOES THE GAP BETWEEN MITER BLOCKS CHANGE? (Y/N)

IF YES, SELECT FROM THE FOLLOWING CHOICES THE MOST ACCURATE DESCRIPTION OF THE CHANGE. (No.)

1. TOP GAP INITIALLY OPEN BUT CLOSES UNDER FULL HEAD.
2. TOP GAP OPENS WIDER BUT CLOSES UNDER FULL HEAD.
3. TOP GAP OPENS AND REMAINS OPEN.
4. TOP OF MITER IS CLOSED BUT GAP OPENS BETWEEN WATER LINE AND TOP.
5. TOP OF MITER IS CLOSED AND GAP BETWEEN WATER LINE AND TOP CLOSES.

ESTIMATE THE MAXIMUM WIDTH OF GAP (in.) ____________

ESTIMATE THE LOCATION OF THE MAXIMUM GAP FROM TOP GIRDER (ft) ____________

OBSERVATIONS FROM BOAT

CORROSION AT SPLASH ZONE (LEVEL 0,1,2,3,4, or 5)

	LEFT LEAF		RIGHT LEAF	
	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM
SKIN:				
GIRDER:				
INTERCOSTAL:				

DENTS -- SKIN PLATE (S), GIRDERS (G), OR INTERCOSTALS (I)

	LEAF L or R	COMPONENT S, G, OR I	LOCATION, DIST. FROM: (ft) TOP GIRDER	QUOIN	SIZE (ft) HEIGHT	LENGTH
(1):						
(2):						
(3):						
(4):						
(5):						

CRACKS -- SKIN PLATE (S), GIRDERS (G), OR INTERCOSTALS (I)

	LEAF L or R	COMPONENT S, G, OR I	LOCATION, DIST. FROM: (ft) TOP GIRDER	QUOIN	SIZE (ft) HEIGHT	LENGTH
(1):						
(2):						
(3):						
(4):						
(5):						

BEARING BLOCK LEAKS @ LEFT LEAF (L), MITER (M), RIGHT LEAF (R)

	TYPE -- L,M,R	DISTANCE FROM TOP GIRDER (ft)	LENGTH (ft)
(1):			
(2):			
(3):			
(4):			
(5):			

SKIN LEAKS @ LEFT LEAF (L), RIGHT LEAF (R)

	GATE L or R	TYPE (H)ORIZ. OR (V)ERT	SHORTEST DISTANCE FROM: (ft) TOP GIRDER	QUOIN	LENGTH
(1):					
(2):					
(3):					
(4):					
(5):					

BOILS @ LEFT LEAF (L), RIGHT LEAF (R), MITER (M)

	TYPE (L,R, or M)	DISTANCE FROM QUOIN (ft)
(1):		
(2):		
(3):		
(4):		
(5):		

MITER LOCK GATE STRUCTURE SAFETY INSPECTION

Calculation date: ________________ Calculated by: ________________

REQUIRED OVERALL VERTICAL GEOMETRY

Positive elevation of sill above any datum, ELSILL (ft): ________________
Sill to bottom of skin plate, GBOT (ft): ________________
Sill to overflow elevation at top of gate, GTOP (ft): ________________

REQUIRED OVERALL LEAF GEOMETRY

Leaf between contact points, GLEMG (ft): ________________
Gate leaf slope, GSLOPE (ft): ________________
Working line tc downstream edge of girder webs, GWORKL (ft): ____________
Quoin contact point to gudgeon pin, GQUOIN (ft): ____________
Woring line to gudgeon pin (positive when contact point is downstream from gudgeon pin), GPIN1 (ft): __________

COMMON GIRDER GEOMETRY DIMENSIONS

Girder contact point to center of nearest end diaphragm along working line, DQPED (in): ________________
Center of end diaphram at miter end of gate to miter contact point along working line, DEDMP (in): ________________
Bottom girder downstream flange extension below web centerline, BGDFD (in): ________________

GIRD3ER ELEVATIONS

Number of girders in the gate leaf, NGIRDS: __________

Girder Number, NGIRD	Vertical distance above sill, VD (ft)
__________	________________
__________	________________
__________	________________
__________	________________
__________	________________

GIRDER DIAPHRAGM SPACING

Top girder of similar pnl NPANLI	Bottom girder of similar pnl NPANLN	Spaces between end diaphragms NDS	Itrcstl spaces btwn adj dphms NIS
____	____	____	____

DEAD AND LIVE LOADS:

Additional dead load, including ice, mud walkway, gusset plates, etc,
ADEAD (lb): ____________________
Quoin contact point to centroid of ADEAD along working line,
XDEAD (ft): ____________________
Downstream edge of girder web to centroid of ADEAD,
ZDEAD (in.): ____________________
Bouyancy force acting on dry weight of gate,
ABUOY (lb): ______________
Quoin contact point to centroid fo ABUOY along working line,
XBOUY (ft): ________________
Downstream edge of girder web to centroid of ABOUY,
ZBOUY (in.): ____________________
Concentrated live load, including walkway and bridgeway,
ALIVE (lb): ____________________

REQUIRED WATER ELEVATIONS -- (FEET ABOVE ELSILL)

Elevation of upper pool,	ELUP (ft):	________________
Elevation of lower pool,	ELLP (ft):	________________
Full submerge elevation,	ELFS (ft):	________________
Operating water elevations,	ELCW (ft):	________________

STEEL YIELD STRENGTH (KSI):

Miscellaneous steel yield strength ____________________

Webs	Flanges	Skin	Stiffeners	Intercostals	Quoin	Diaphragms
____	____	____	____	____	____	____

GIRDER WEB THICKNESS (in.)

Groups of similar girders		Web end zone	Web center zone
Top girder	Bottom girder	thickness	thickness
NGIRDI	NGIRDN	GWET	GWCT
______	______	______	______
______	______	______	______
______	______	______	______

GIRDER FLANGES, UPSTREAM (in.)

Groups of similar girders		Upstream flange widths		
Top Number	Bottom Number			
NGIRDI	NGIRDN	GUFEW	GUF34W	GUF4CW
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______

Upstream flange thickness		Upstream flange cover plate		
		Distance from Quoin	Width	Thickness
GUFFET	GUFCT	GUCPX	GUCPW	GUCPT
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______

GIRDER FLANGES, DOWNSTREAM (in.)

Groups of similar girders		Downstream flange widths	
Top Number	Bottom Number		
NGIRDI	NGIRDN	GDFEW	GDFCW
______	______	______	______
______	______	______	______
______	______	______	______

Downstream flange thickness		Downstream flange cover plate		
		Distance from Quoin	Width	Thickness
GDFET	GDFCT	GDCPX	GDCPW	GDCPT
______	______	______	______	______
______	______	______	______	______
______	______	______	______	______

GIRDER FLANGE COORDINATES (in.)

Groups of similar girders		Flange splice distance from Quoin	
Top No.	Bottom No.	Upstream	Downstream
NGIRDI	NGIRDN	GUFX4	GDFX5

GIRDER WEB STIFFENERS (in.)

Groups of similar girders		No. trans. stffnr	No. of long
Top No.	Bottom No.	spcs btwn intrmdt dphr	stffnr pairs
NGIRDI	NGIRDN	NGWTS	NGLS

Longitudinal stiffener geometry

Stiffener number 1			Stiffener number 2			Stiffener number 3		
	Width	Thickness		Width	Thickness		Width	Thickness
GLS1D	GLS1W	GLS1T	GLS2D	GLS2W	GLS2T	GLS3D	GLS3W	GLS3T

INTERCOSTAL AND SKIN PLATE GEOMETRY (in.)

Groups of similar intercostals

Top girder no.	Bottom girder no.	Skin plate thickness
NPANLI	NPANLN	SPT

Depth (perp to skin)	Stem thickness	Flng width	Flng thickness
ODI	STEMT	FWI	FTI

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